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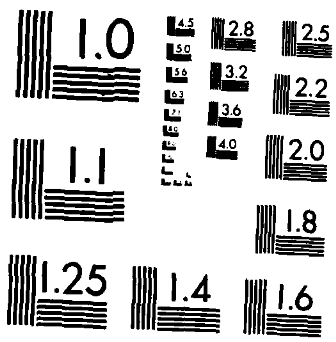

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THREE SUB-SAHARAN MINERALS:
US INTERESTS AND RESPONSES

by

432d Military Intelligence Detachment
(Strategic)

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FOREWORD

This report was prepared by the 432d Military Intelligence Detachment (Strategic), which is assigned the mission of supporting the US Army War College by the preparation of studies and analyses of strategic military significance. Operational training guidance is provided by the Strategic Studies Institute. Mr. James E. Trinnaman served as project coordinator.

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THREE SUB-SAHARAN MINERALS: US INTERESTS AND RESPONSES

INTRODUCTION

This paper examines problems associated with three critical materials that are mined in sub-Saharan Africa and recommends policy responses. An in-depth evaluation of the uses, sources, transport and processing of the Platinum Group Metals (PGM), chromium and manganese is presented.

These materials were chosen as they are among the most critical to our defense effort and to the industrial base on which our security ultimately depends. Domestic production of these materials is negligible or nonexistent and over half of the world's reserves and/or production are found in Southern Africa and the USSR.

The manganese produced in the USSR is consumed largely within the East Bloc, but the USSR is a significant source for the Free World's chromium and PGM. Potential expansion of Soviet influence in Southern Africa could have significant political/economic benefits for the USSR which needs Western currencies to support imports of agricultural products and high technology.

The Republic of South Africa (RSA) is the principal producer of PGM's in the Free World, followed by the Soviet Union and Canada. Recycling accounts for a significant portion of US supply. In an emergency, a substantial portion of consumption could be diverted from catalytic converters on automobiles.

However, in the case of chromium and manganese, much larger tonnages are required and substitution and diversion are less practical. Zimbabwe is a significant producer of chromium, with a potential to expand production to or beyond levels achieved before black liberation forces disrupted production during their successful fight to overcome minority white rule. Gabon competes with RSA as a major exporter of manganese to the world.

US concern about access to these minerals is often cited as a reason to develop a more evanhanded approach to the RSA despite its racial policies. In the case of chromium and manganese, Zimbabwe and Gabon play important roles as producers in competition with the RSA. Policymakers continually should evaluate support for the development of minerals in black Africa as a partial alternative to continued heavy reliance on South African production.

CHROMIUM

Description and Industrial Application. The mineral chromite consists of varying percentages of chromium, iron, aluminium, and mangnesium oxides which generally are categorized by the end use: metallurgical, chemical, and refractory.

Chromium is an essential and versatile element which satisifies a wide range of industrial applications, including the manufacture of stainless steel, tool and alloy steels, heat and ocrrosion resistant materials, special/super alloys, alloy cast irons, metal plating, ball bearings, and missile and aircraft components. (See Table 2 for end uses of chromium.) Chromium enhances hardness, wear-resistance and impact strengths of alloy metals. Chromium alloys are used in the manufacture of commercial and military aircraft engines, helping improve fuel efficiency and noise level. Approximately 1656 pounds of chromium are required for the manufacture of the Pratt and Whitney F-100 turbofan engine in the F-15 and F-16 aircraft.[1]

Production-Resources-Supply. The RSA has been the world's largest producer and exporter of chromite ore in recent years, accounting for more than one-third of the total world production.[2] Presently the RSA and Zimbabwe satisfy 40 percent of the total world chromite requirements, matching the production of the Soviet Union, Albania, and COMECON states. Western industrialized states rely heavily on South African chromite exports (Japan, 46 percent; United States 35 percent; United Kingdom, 60 percent; Federal Republic of Germany (FRG), 40 percent; and Italy, 20 percent).[3]

Metallurgical-grade chromite contains 35-54 percent chromium oxide and comes from layered or stratiform deposits and pod-type deposits. Stratiform deposits contain the bulk of the world's chromite reserves, which are located primarily in the Bushveld Complex in the Transvaal Province of South Africa, followed by the Great Dyke in Zimbabwe. The Bushveld Complex reserves are estimated at 2.5 billion tons with an additional sub-economic reserve of 22 billion tons. Most of the Bushveld chromite is a high-iron variety. The Great Dyke region contains an estimated reserve of 560 million tons of high-chromium chromite and 56 million tons of high-iron chromite.[4]

During the past decade a significant economic shift in the world's chromium market has occurred, causing substantial declines in chromite exports and increases in chromium ferroalloy exports. The ferrochrome exports in 1970 from ore producing countries totalled 440,000 metric tons (MT). By 1979 export production tripled to 1,370,000 metric tons.[5] In 1960 the consuming industrial countries produced the majority of chromium ferroalloys, with US ferrochrome production about 39 percent of the Free World's total output. Yet, by 1980, the ore producing countries accounted for more than 50 percent of the total world's ferrochrome processing, with US processing capacity decreasing to 10 percent.[6]

This market shift will contine in favor of ore producing countries because they are expanding their processing facilities to obtain added export value. The ore consuming industrial countries' older, less efficient processing plants are losing the competitive edge to foreign processors. Reportedly, by 1983, an additional 200,000 MT/yr of ferrochrome production capacity will supplement existing ferrochrome facilities in Zimbabwe, Albania, Greece, India and the Philippines.[7] Concurrently, the largest US ferrochrome processor, Macalloy Incorporated of Charleston, South Carolina--which could satisfy about 30 percent of US demands for ferrochrome--currently is being administered under Chapter XI of the US

Bankruptcy Act.[8] Other US chromium ore processing plants have ceased production due mainly to unprofitability, obsolete techniques, energy inefficiency, violation of environmental (EPA) laws, and labor costs.

Domestic mine production of chromite ceased in 1961. Today the United States remains totally dependent upon foreign imports. From 1977 to 1981 US industry annually consumed about 525,000 MT of primary chrome, processed each year from an average of more than 1.7 million MT of chromite ore imports. The economic recession in the United States reduced chrome consumption in 1981 to 436,000 MT, and 1982 consumption is being projected at 480,000 MT. Current estimates project the United States, Japan, and Western industrialized countries consuming chrome at an annual growth rate exceeding three percent. By the year 2000, US consumption of chrome will exceed 1,000,000 MT per year.[9]

<u>Other Free World Sources of Chromite.</u> As indicated in Tables 1 and 3, other Free World sources of US imported chromite after RSA and Zimbabwe are Finland, Philippines and Turkey. Approximately 9 percent of Finnish chromite exports and 33 percent of Philippines chromite exports are shipped to the United States. Turkish chromite production, on the other hand, has decreased from 581,000 MT in 1976 to about 372,000 MT in 1981, although production capacity is estimated at 700,000 MT/yr.[10] Turkish exporters demand $110 per MT for their metallurgical grade ore, which is twice the market price for lower grade chromite from RSA. About 20 percent of Turkish chromite production is shipped to the United States and the balance goes to Western Europe and COMECON countries. Brazil, Greece, India, Iran and Madagascar mine and ship about 1.35 million MT of chromium ore, of which 60-70 percent of the output goes to Japan and the balance is shipped to major industrialized states of Europe and COMECON. Presumably the United States could compete for these supplies if RSA exports ceased, but not without drastic upward pressures on the unit price of chromite and adverse effects on US trade and relations with competing industrial states.

East Bloc Supplies to the West. During the past five years the United States has relied upon the USSR for 15 percent of its chromite requirements. Much less significant shipments of the Soviet ore are made to West Germany, France, Japan and Sweden. Soviet chromite exports show a noticeable decline in chromium content, rendering its ore less desirable to the US metallurgical industry. Albania has become a significant exporter of chromite by producing more than one million MT of chromite for export each year since 1978. About 5 percent of US chromite requirements come from Albania. While Yugoslavia has almost exhausted its chromite mine production capacity, it converts about 300,000 MT of Albanian and Soviet chromite to ferrochrome for export to the United States and Europe.[11] (See Table 1)

World Resources of Chromite. The US Bureau of Mines identifies about 36 billion tons of shipping-grade chromite available on earth to satisfy world industrial demand for centuries. The combined chromite resources of RSA (almost 25 billion tons) and Zimbabwe (11 billion tons) account for 99 percent of world resources. The balance of the world's resources is measured in millions of tons and is distributed among a dozen chromite producing countries listed in Table 3. US chromium resources lie in the Stillwater Complex in Montana and in beach sands of Oregon. Given supply conditions from foreign sources, development of substantial domestic chromite mining in the United States is not probable in the near future.[12]

US Recycling. During 1981, 10 percent or about 44,000 MT of total US demand for chromium was satisfied by recycled chromium extracted from stainless steel scrap. Research programs of the Bureau of Mines concern the recovery of chromium from laterites (chromium contained clay deposits) and low-grade ores, reclamation of chromium from stainless steel, recovery of chromium from metallurgical and mining wastes and the appraisal of chromite resources in Alaska and northwestern United States.

Chromium Stockpile. The Federal Emergency Management Agency (FEMA) goals are to maintain 3-year supplies of designated types and grades of chromite and chromium ferroalloys as they relate to national defense end-uses. Table 4 lists the specific chromium materials and inventory levels. There are shortages of 40-80 percent in each category except for chromium ferroalloys, which exceed the stockpile goal by more than 100 percent. However, closer examination of the stockpile goals shows that the actual materials on hand are largely in the form of chromite ore which would be difficult to process into ferrochrome, given the shift in processing capability to producing nations. The total stockpile of 688,000 metric tons of all ferrochromium is clearly inadequate, even though it exceeds the goal.

Chromium Substitutes and Alternatives. Although stainless steel can be made without nickel, chromium is essential for high quality and performance standards. Nickel, cobalt, columbium, vanadium or molybdenum can replace chromium in some alloys, but at a higher cost and possible lower performance.[12] High strength steels, high temperature metals, and corrosion-resistant alloys essential for jet engines and petrochemical and power plant equipment are totally dependent on chromium.[13] Superalloys used largely in the manufacture of aircraft gas turbines are uniquely dependent on chromium.[14] Although chrome content can be fractionally reduced, total substitution in metallurgical, chemical, and refractory industries is presently limited.

Other chromium substitutes are aluminum and plastics for decorative trim, nickel or cadmium for corrosion protection in iron and steel alloys, titanium in manufacture of chemical processing equipment, and magnesite and zircon for some refractory materials. The Bureau of Mines is conducting studies of producing chromium-free and low-chromium substitute alloys for use in the manufacture of stainless steel. However, it is clear that national defense industries rely

heavily upon chromium in order to produce almost all grades of steel for most weapons systems and military aircraft, ships and vehicles.

Research and development of sophisticated new plastics, ceramics and metallic products may decrease US dependence on chromium in some applications. Technological breakthroughs such as the development of carbon-fiber composites by the Northrop Corporation exemplify the US industrial capabili[illegible] to develop synthetic substitutes. Carbon-fiber composites are now used in t[illegible] manufacture of airframe structures and sections of aircraft wings, fins and [illegible]. The composites have several advantages over metal counterparts, particularly since they can be molded in forms to create large assemblies without machining individual parts. Also, structural strength can be monitored and enhanced directly. Reportedly, Hercules, Inc., is planning to construct 72-foot MX missile launch tubes from carbon-fiber composites. Wider industrial use should reduce the cost of production from the current selling price of $20 per pound, compared to less than $1 per pound for most standard steel grades.[15] Sophisticated new products are not likely to lessen the importance of chromium for some time.

MANGANESE

<u>Description and Industrial Application.</u> Every year the US steel industry uses approximately 95 percent of all manganese shipped to this country. Steel and ironmakers annually require nearly one million metric tons of ferromanganese and manganese ore to make steel and iron.[16]

Between 12 and 16 pounds of manganese metal content are required for each ton of steel produced. Manganese has no satisfactory substitute and the United States has no domestic mine production of manganese of useable grade for the steel industry. Additionally, manganese is essential to the manufacture of batteries and to basic applications in the ceramic, chemical and welding industries.[17] (See Table 2 for a description of uses of manganese.)

Production-Resources-Supply. Metallurgical-grade manganese ore normally contains 35-54 percent manganese content. Ferromanganese, the usual form of manganese used in steel fabrications, ranges in mineral content from 74 percent to 95 percent. The United States has no mine production of metallurgical-grade manganese ore since the majority of domestic mines and resources are low-grade ores of less than 35 percent metal content.[18] Arizona, Arkansas, Colorado, Maine and Minnesota have substantial deposits of low-grade ore, comprising a large, marginally economic reserve for the United States.[19]

Table 2 reflects heavy US reliance upon Gâbon and RSA for more than one-half of the manganese ore imported each year, and upon RSA for almost 40 percent of US ferromanganese requirements. While the USSR is the largest producer (table 3), it has reduced exports to its COMECON partners, forcing East Bloc steel producers to compete with Western industrial states for manganese from Brazil, Gabon, India, RSA and other Free World suppliers.[20] The major managanese mine producers are shown in Table 3.

As with US ferrochrome production, domestic production of ferromanganese required for steelmaking has decreased steadily since the mid-1950's through the 1960's when the United States led the world in ferromanganese conversion (and steel production). A variety of causes brought about the decline: a net reduction of steelmaking in the past decade; technical improvements in steelmaking and ferromanganese conversion; high cost of energy, labor costs, environmental controls; taxes and trade regulations, both US and external; and the prohibitive capital costs of new construction or modernizing technically obsolete, inefficient and unprofitable facilities.[21] From 1965, when the United States imported over two million MT of manganese ore for ferromanganese conversion in steelmaking, to 1981 with only 426,000 MT of ore imported (Table 1), a dramatic shift occurred in ferroalloy industries. It has become more profitable for the ore mine producing

countries to build ferroalloy conversion plants to add metal content and dollar value to their exports than to sell bulk ore to industrial consuming countries at lower unit prices. Consequently, the RSA, Gabon, Brazil, Australia, India, and Ghana and Mexico have become major ferromanganese producers while ferroalloy production in the the United States, Japan and Western Europe has declined. Additionally, the trend toward declining ferromanganese production in the United States is accompanied by the sale of US ferroalloy plants to foreign corporations. For example, Union Carbide sold its three US ferromanganese plants in West Virginia and Ohio to a Norwegian consortium in June 1981, and is similarly disposing of its two Canada-based plants.[22] The US Bureau of Mines reports that recent transfers of ownership of US-based electric-furnace ferroalloy plants has placed US production of ferromanganese predominantly under foreign ownership. Consequently, the United States has lost its former predominance as the price-setter of the ore market and now pays the market price influenced by Japanese ore purchasers and ferroalloy prices set by foreign producers. Therefore, the effectiveness of bargaining power of US purchasing managers is not clear, given the competition between US and foreign demand for manganese ores and ferroalloys.[23]

World Resources of Manganese. Tables 1-3 list the Free World sources of manganese ore and ferromanganese. The US Bureau of Mines predicts a world demand for manganese of about 400 million tons from 1975 through the year 2000. This forecast assigns a 1.7 percent annual growth rate to US demand for the ore and 3 percent for the rest of the world.

With more than 80 percent of the world's identified resources located in the USSR and RSA, and estimates of RSA reserves ranging from one billion to nine billion tons, there should be no world shortage of manganese in the foreseeable future. Distribution of world resources of the ore is allocated as follows:

Southern Africa, 50 percent; USSR, 35 percent; Mexico and the United States, 3 percent; Argentina, Brazil and Chile, 2 percent; China, India and Thailand, 2 percent; Australia and Oceania, 5 percent; Ghana, Morocco, Upper Volta and other African states, 3 percent. The RSA resources account for more than 75 percent of the ore located in the Free World or "Market Economy Countries."[24] The USSR does not export manganese ore or ferromanganese to the West. India presently bans exports of metallurgical ores and ferromanganese, and China's small exports of ore are limited to Japan. Consequently, the United States, UK, France, West Germany, Norway, Italy and Benelux countries rely upon the RSA, Gabon, Australia, Brazil, Mexico, and Zaire for manganese imports.[25]

Vast deep-sea deposits of manganese oxide are found over large areas of the ocean floors in the depths of one to three miles. In the form of nodules, these manganese deposits also contain nickel, copper and cobalt. Because of the prohibitive research and initial operating costs, plus the risk of loss because of the uncertainties of international law, no private firm or venture group has launched any sustained deep seabed exploration and mining operation. The Law of the Sea Conference has been delayed by disagreements between developing nations and industrial states over control of deep ocean mining rights, technology, and marketing. Presently, the Reagan Administration is seeking changes in the draft agreement of the conference.

Manganese Stockpiling. There are no significant manganese recycling processes or programs, and there is no feasible substitute for the ore in steelmaking or other major applications. Stockpiling has been the US Government's most effective program in maintaining required levels of supply of strategic manganese ores and ferroalloys. Table 4 shows surpluses in three of five stockpile categories and only an 11 percent deficient of metallurgical ore. Additionally, FEMA has about 872,000 MT of useable, nonstockpile-grade metallurgical

ore. The stockpiling of manganese under FEMA is more complete than the levels of supply for other government stored strategic minerals.[27]

PLATINUM GROUP METALS

Description and Industrial Application. The platinum group metals (PGM) consist of six closely related metals: platinum, palladium, rhodium, ruthenium, iridium and osmium. The metals commonly occur together in nature and are among the most scarce of the metallic elements. They occur as native alloys or mineral compounds in placer (streambed) deposits, sometimes associated with gold, and in lode deposits in basic or ultrabasic (low silica content) rocks, where they are frequently associated with nickel and copper. Nearly all of the world's supply of these metals currently are extracted from lode deposits in three countries--the RSA, the Soviet Union and Canada.

In South Africa, PGM's are mined as primary products with copper, cobalt, gold and nickel as by-products. Osmiridium, a native alloy combining osmium and iridium, is recovered from some South African gold ores as a by-product. PGM's and gold are co-products in the placer deposits of Canada and the USSR. In the United States and other producing countries, PGM's are almost entirely by-products, as in US nickel-copper mines.

Platinum's unique physical and chemical chracteristics are used in special high technology industrial applications because of wear resistancy, high melting point (3200^{o}F), greater resistance to corrosion and attack from acids, and the ability to catalyze a variety of chemical reactions. Its greatest consumption in recent years has been in automobile catalytic converters, which reduce the noxious content of exhaust fumes. Refining and other chemical industries are major consumers, as are the electrical, communications and electronics industries, and dental and jewelry industries. Of the 2.35 million ounces of PGM's consumed

by US industries in 1981, the automotive, chemical and petroleum refining industries used PGM's primarily as catalysts.[28] (See Table 2 for uses.) Other industries needed PGM's in order to employ their inert chemical quality and refractory characteristics.

Platinum. The use of platinum as an automotive-emissions-control catalyst may be phased out by 2000 because of alternatives to the standard gasoline internal combustion engine, such as stratified-charge, diesel, and lean-burning engines, plus more precise control of ignition and carburation by electronic devices, improved fuels and electric-powered vehicles. However, through 1990, the use of platinum, rhodium, and possibly palladium as automotive catalysts will increase as more vehicles are required to employ catalysts and as increased PGM content for converters is required to meet higher standards. The US Bureau of Mines forecasts an annual growth rate of 1.5 percent in US demand for PGM's through 1990.

In petroleum refining, demand for platinum is offset by the amount of lead compounds permitted to be retained in gasoline and by the use of low-octane gasolines. The successful marketing of diesel engines reduces the demand for catalytic converters. The development of nonplatinum petroleum-reforming catalysts and the use of gasoline additives, such as alcohol, will also reduce demand for platinum. Platinum is used in oil shale or coal processing, but large demands for this use are not forecast.

Demand for platinum in the glass industry will continue as glass fiber continues to displace textile fibers and glass-reinforced plastics displace structural metals. Additionally, energy conservation and federal tax credits draw greater use of glass fiber in home and building insulation.

The use of platinum in electrical and communications equipment and in other electronic devices continues to expand with the growth of computers and high-technology products. For example, Japanese electronic equipment manufacturers used four times as much platinum for making semiconductors in 1981 than several years ago. Demand may be offset by substitute metals, miniaturization, and solid-state devices that reduce reliance upon platinum.

Palladium. Uses of palladium can be found in the communications, chemical, oil and glass manufacturing industries, in addition to requirements from the dental-medical field.

The telephone industry is the major user of palladium, employing it in electromechanical switching equipment. Practice now dictates that alloys (60 percent palladium, 40 percent silver) be used in contacts for switching equipment.[29] Yet, despite the growth of solid state technology, demand should continue at a reduced rate.

The demand by the chemical industry for palladium normally corresponds to that of platinum. The high cost of petrochemical feedstocks and the continued economic recession in the United States and other market economies have reduced demand. In the emissions-control industry and in the petroleum refining and glass industries, palladium has applications as a catalyst similar to the catalytic and chemical uses of platinum. The rate of growth in demand for palladium is likely to follow the demand for platinum.

The trend of consumption in the dental and allied medical fields indicates that palladium demand in those industries could more than double by the year 2000, due mainly to increased dental maintenance and as a replacement of gold in prosthetic dentistry.

Rhodium. Rhodium has few applications by itself--as a catalyst for acetic production, in plating white-gold jewelry and in plating electrical parts, such as

commutator slip rings. Rhodium's primary use is as a component of platinum alloys. Rhodium demand follows the demand for platinum.

In the glass industry, rhodium is alloyed with platinum, forming dispersion strength alloys used in making specialty glass. In the jewelry field, rhodium is often plated on base metals, but because of its high cost, less expensive materials are sought in substitution.

Rhodium use in automobile catalysts is expected to be high through 1990.

Ruthenium. Chemical and electrical industry sales account for most of the consumption of ruthenium. In the chemical industry, ruthenium is in oxide coatings on titanium anodes for the electrolytic manufacture of chlorine and caustic soda both high tonnage industrial chemicals. Because of its catalytic properties, ruthenium also is used in the production of certain specialized organic intermediaries by chemical and pharmaceutical companies.

Increased usage is expected in electronic and chemical applications as a resistor material in thick-film and hybrid integrated circuits, as contact material in communications equipment, and in electronic plating. Use of ruthenium is favored over some other PGM's because of price and supply advantages.

Iridium. Traditional markets for iridium are found in the electrical, chemical and jewelry fields. In the early 1970's, however, a significant petroleum industry application was developed. Sporadic purchases by the petroleum industry have contributed to iridium's erratic demand pattern and volatile prices. Iridium is used as a reforming catalyst with platinum in petroleum refining.

Increased iridium applications are as crucibles in crystal growing; as an alloying element in special electrical contacts; in aircraft engine sparkplugs and fusewire for explosive detonators; and as chemical catalysts, especially iridium-based catalysts for the emergency power units in military aircraft.

Osmium. Significant applications are yet to be found for osmium, the most dense element occurring in nature. Limited uses have been developed in chemical, dental and medical fields. Undesirable properties of osmium generally preclude use in electrical and jewelry applications.

Domestic Demand. The US demand for platinum-group metals is forecast to grow at an annual rate of 2.5 percent for the remainder of the century, to about 3.2 million troy ounces in 2000. At this rate of growth, the nation will require about 40 million troy ounces of primary metal through the year 2000. Annual demand in the rest of the world, which is forecast to grow slightly faster than in the United States, is expected to reach about 8.6 million troy ounces in 2000.[30] World reserves and resources are more than adequate to meet this demand (Table 3).

Domestic production of the three principal metals of the platinum group (platinum, palladium and rhodium) will probably remain short of satisfying demand even if the Stillwater Complex deposits in Montana were developed. These deposits could supply most of the US requirements for palladium and about one-fourth of platinum requirements. Without such development, the United States will continue to import virtually all required primary PGM's well into the future.

World Sources. Of the 6.8 million troy ounces of PGM's produced in the world during 1980 and again in 1981, the RSA and USSR mined 94 percent of the total (Table 3). The RSA provides most of the US requirements for PGM's followed by the USSR and UK (Table 1). The UK has no mines, but processes ore concentrates received from RSA and Canada. Total world resources of PGM's are estimated at 3.2 billion troy ounces, exceeding projected world demand through 2000 by 20 times.

The huge resources of the RSA are in three horizons (strata of soil) in the Bushveld Complex, in the Transvaal Province surrounding Pretoria. RSA mining of PGM's, with the largest reserve base of these metals in the world, is supported by substantial capital for expansion and abundant sources of unskilled workers for this labor-intensive industry. An estimated 85,000 black workers mine PGM's. However, RSA mine operators must cope with increasing shortages of skilled (mostly white and Asian) labor and relatively sharp increases of wages for unskilled workers.[31]

Canadian and Soviet PGM's are almost entirely by-products of nickel mining. Canadian reserves are identified at Sudbury, Ontario, and in the Lynn Lake-Moak Lake region of Northwestern Manitoba. Soviet reserves are located primarily in the Norilsk-Talnakh nickel-mining area of Northwestern Siberia, with lesser tonnages at Pechenga and Monchegorsk in the Kola Peninsula.

US resources of some 300 million troy ounces are concentrated in Alaska, Montana and Minnesota. Of these resources, only 16 million ounces constitute the US reserve base (Table 3). However, domestic reserves could be increased dramatically if exploration and feasibility studies prove that the deposits in the Stillwater Complex of Montana and Duluth, Minnesota, are economically mineable. Most US identified reserves comprise by-product PGM's in copper ores in the western states. The estimated reserves of PGM's in the United States, as compiled by the US Bureau of Mines and US Geological Survey, are as follows: Alaska, 20 million troy ounces; Minnesota, 50 million ounces; Montana, 225 million ounces; and others (including copper porphyries), 5 million ounces.[32]

Recycling. Although platinum and palladium prices* fell 30-50 percent in 1981 compared to 1980, the amount of PGM's recovered from scrap increased more than 10 percent. This increase in PGM recovery, despite the economic recession

*Platinum price fluctuated between $400 and $500, and palladium dove from $142/oz to $69/oz and hovered around $100/oz by end of 1981.

and marked price reductions, is attributed to the industrial nature of PGM applications as compared to gold and silver. Jewelry no longer represents a significant portion of platinum use in the United States. About 350,000 ounces of PGM's were recovered in 1981, of which 170,000 ounces were platinum, 165,000 ounces were palladium, and the balance of rhodium, iridium and ruthenium.[33] Only a few ounces of osmium were recycled according to US Bureau of Mines data. These figures do not include more than one million ounces of PGM's recovered by petroleum and chemical companies that retain ownership of spent catalysts and do not offer the secondary PGM's for resale.

Although the automotive industry is by far the largest potential source for recycling PGM's, a large portion of scrap presently used for recycling comes from the electronics and dental fields. By the mid-1980's, however, automotive catalytic converters will be the largest source of recycled platinum. Presently, recycled PGM's amount to 15-18 percent of total sales to industry. The US Bureau of Mines has conducted research for improving processing of domestic PGM ores, recovering PGM's from electronic scrap and electrodeposition of PGM industrial coatings.

Stockpiles. Total platinum stocks in the US National Defense stockpile could supply domestic industry for about four months, and palladium stocks could satisfy current demand for one year. (See Table 4.)

Substitutes. High costs spur government and industry efforts to find substitutions for PGM's unless the technical compromises are not justified by the loss of PGM's unique qualities. Generally, substitution of metals within the platinum group, especially in alloys, is easier than using alternative non-PGM materials. For example, iridium and ruthenium substitute fairly readily for each other as hardeners in platinum-based alloys used for some types of electrical

switch contacts. Platinum and palladium are interchangeable to a limited degree in dental alloys. Alternate materials in electrical uses include tungsten, nickel, silver, gold and silicon carbide. Palladium and ruthenium were partially substituted for gold in some electrical applications because of sharp price differentials between metals in 1979.

Several types of catalysts may replace PGM's in some chemical processes, but with losses of efficiency and increased operating and capital costs. Examples are catalysts containing the transition metals, such as rare-earth elements, nickel, molybdenum, tungsten, chromium, cobalt, vanadium and silver and their compounds. However, substitution of rhenium for platinum as a petroleum reforming catalyst has produced significant improvements over platinum. In applications requiring resistance to corrosion, substitute materials, such as stainless steel and ceramics, can be used, but with the risk of a shorter useful life or some contamination of the product. Gold, silver and tungsten are substitutes in electrical and electronic PGM uses.

PGM Movement. Most of RSA's annual production of 3.1 million troy ounces (about 97 metric tons) of PGM's are shipped by cargo aircraft in the form of concentrated ore or refined metal. Other producers and refiners air freight PGM's as anode slimes and scrap. PGM's contained as by-products in nickel-copper matte are shipped by surface transportation.[34]

STRATEGIC MOVEMENT

Lines of Communication. The mining industries and supporting transportation infrastructure in RSA, Zimbabwe and Gabon are relatively modern and efficient by Western industrial standards. Table 5 describes the rail and highway routes from the mine producing areas to the ports of shipment, and the sea routes from the ports of shipment to receiving ports in the United States. All of the mining areas

in the RSA and Zimbabwe are serviced by well-developed, high-capacity railways and/or highways which connect with deepwater ports on the Indian Ocean.

However, the Zimbabwe-Mozambique railway and its port terminal at Maputo operate at a much reduced capacity because of damage and lack of maintenance during the armed conflicts for Zimbabwe independence.[35] Each port has specialized ore handling facilities or equipment for bulk loading of chromium or manganese ores. For RSA and Zimbabwean ores, there is flexibility in routing shipments through Maputo, Durban or Port Elizabeth, if political and economic circumstances permit such cooperation. The mode of shipping manganese ore from the mine at Moanda, near Franceville, Gabon, differs markedly from ore movement in Zimbabwe and the RSA. The Gabonese mine is linked to the Congolese railhead at Mbinda by a 48-mile cable rail-way system. At Mbinda the ore is loaded into railcars for movement 300 miles south to the Congolese deepwater port at Pointe Noire for export. Reportedly a Trans-Gabon railway will connect the Moanda mining area with modern deepwater port facilities at Owendo, 15 miles from the Gabonese coastal city of Libreville. The direct rail link will supplement and improve the movement of manganese from Gabon.[36]

Port Conditions. RSA ports are well maintained and efficiently operated, with few delays affecting working cargo vessels. Ships at Maputo and Point Noire occasionally experience delays waiting to berth.[37]

Labor conditions have been realtively stable and without serious work stoppages or strikes. However, internal conditions in the RSA, because of oppressive apartheid policies and economic discrimination against blacks, spawn civil disturbances that can disrupt port operations or rail shipments until RSA authorities quell such outbrusts. Guerrilla interdiction and sabotage of RSA rail operations and attacks on fuel depots are increasing in frequency and violence, but with minimal effect upon RSA exports. Such attacks are

attributed to the African National Congress (ANC), a major, outlawed black political force in South Africa. Disruptions of cargo movement have been sporadic and temporary, with RSA authorities quickly repairing blown tracks, bridges and overhead power calbes.[38]

Sea Lines of Communication. The average distance travelled by ore carriers loading chromium ore at ports in RSA, Philippines, USSR, Finland, Turkey and other chromite producing countries and delivering their cargoes at US Atlantic and Gulf Coast ports is 7,600 nautical miles. The average transport distance for manganese ore is 5,100 nautical miles. However, the distances and difficulties of the voyages characterizing these sea lines of communication (SLOC's) vary greatly. Shipments from Brazil and Mexico reach some US ports in less than 3,200 nautical miles, while cargoes from the Philippines and Australia are hauled 8,000 to 10,000 miles.[39] Delibery, cost, time, seasonal changes of weather, and seas are practical constraints in selecting sources of ore with long SLOC's.

Chromium ore shipments are primarily received at the Gulf Coast port of Burnside, LA, and the Atlantic Coast ports of Baltimore, MD, and Charleston, SC. At Burnside, most of the ore is transferred into barges for distribution to alloy, chemical and refractory plants on the Mississippi-Ohio inland waterway system. Manganese ores are received at Burnside and Baltimore, but also are shipped to Philadelphia and to inland ports through the St. Lawrence Seaway.[40]

Cargo Fleets. With the decline and near-disappearance of the US flag merchant fleet, the United States relies upon the foreign-flag bulk carrier fleet in order to secure critical supplies of chromium and manganese ores. Most of these bulk cargo vessels are owned or controlled by US companies operating under Liberian or Panamanian registry in order to avoid expensive labor costs for US crews and other high operating expenses of US flag vessels.[41] Accordingly, US national defense industries are dependent upon many American-controlled,

Liberian and Panamanian registered ships which are crewed by Greek, Italian, Spanish, Philippino and Taiwanese merchant seamen.

In June 1981, Secretary of Defense Weinberger clarified DOD policy on "flags of convenience" ships supporting the national economy and military sealift requirements during times of war or national emergency. He reaffirmed the US Government's support of the concept of effective US control (EUSC) over American-owned or controlled vessels, which come under direct US Government control in the event of war or national emergency.[42] The EUSC fleet is composed of some 460 to 480 oil tankers, general and bulk dry cargo vessels, passenger, refrigerator and other special purpose ships (see Table 6), which are owned or controlled by US companies. Of these EUSC vessels, DOD considers 54 tankers and 15 dry cargo vessels of direct use to military sealift operations.[43] The balance of the EUSC fleet would support the US national economy by transporting critical materials. The fleet is considered a national defense resource and is factored into contingency planning of sealift requirements.[44]

Criticism of the EUSC fleet as unreliable during times of crisis does not bear up to assessments of the fleet's operations during and since World War II. There is no record of an American-controlled ship refusing to comply with a direction from the US Government during a time of war or national emergency. The foreign crews aboard EUSC ships have not shown any disloyalty to the United States to date. Experience indicates that US companies controlling such ships hire proven and reliable crews with friendly national origins.[45]

Soviet Interference. US access to secure and economically viable American-controlled ships is being jeopardized by Soviet and Third World agitation against open registry shipping. The Soviet objective is to convince developing ore producing countries to require that ore shipments be carried on national flag

vessels rather than on vessels under flags of convenience. If such a scheme were adopted by the UN Conference on Trade and Development (UNCTAD), US-owned flag-of-convenience carriers would be adversely affected and security of shipment would be reduced.[46]

Soviet sea power and global influence has expanded drastically since the Cuba crisis 20 years ago. With a combination of base (Ethiopia and Angola) and port call rights (Mozambique and Guinea), established anchorages (Socotra and Seychelles Islands) and a network of overflight rights, Soviet naval and air reconnaissance elements can surveil and monitor traffic along strategic sea lanes through the Western Indian Ocean, Mozambique Channel, around the Cape of Good Hope and north through the South Atlantic.[47] Relatively few US and allied naval and air reconnaissance assets are available around the Cape and South Atlantic to offset Soviet presence and influence or to preempt possible interdiction by the Soviets of supply movements.[48]

CONCLUSIONS

Chromium. The wide variety of chromium's end-uses makes it the most critical of the metals studied. It has direct military use in jet engines and essential industrial applications in refractory linings for furnaces used in fabricating steel and metal alloys.

Few opportunities exist for substitution and design changes to reduce chromium consumption. There are no substitutes for some critical applications of chromium metal. Programs to conserve consumption through substitution of other metals could reduce use by one-third, but further substitution would cause substantial economic penalties.

World reserves of chromium ores are adequate and existing capacity to produce ferrochromium exceeds demand. However, the Soviet Union, RSA and Zimbabwe control over 80 percent of the world's production and changes in their production capacities or exporting practices can have adverse effects on the economies of the consuming countries.

No mines operate in the United States and other sources are quite distant--Finland, Philippines and Turkey. US vulnerability has been futher exacerbated by the decline of domestic smelting capability because of several plant closures and the technical bankruptcy of the largest US smelter, which continues operation under Chapter 11 administration.

A program of converting the large supply of chromite in the stockpile into ferrochromium by domestic smelters would accomplish two objectives. It would provide profitable activity for domestic smelters in order to preserve a minimum processing capability needed in emergency. Furthermore, it would convert the chromite now in the stockpile to useable form in the event of an interruption in supply.

Another policy consideration pertains to the production capacity and large chromite reserve of Zimbabwe. While its current production of chromite has declined 40 percent since 1975 to 554,000 MT in 1980 (Table 3), about 75 percent of the ore is converted to ferrochrome and projected expansions will increase Zimbabwe's smelting capacity by 75 percent.[49] With increased production, Zimbabwe could replace the USSR's exports to the West, thereby reducing the risk of Soviet manipulation of the chromium market causing destabilizing effects upon Western economies.[50]

However, Zimbabwe's ferrochrome industry requires substantial investment capital for power plants, transportation infrastructure, and recruitment of skilled labor. Outside financial support is essential and the United States supports

Zimbabwe's plans to expand its ferrochrome industry.* However, even with prudent development plans and adequate funding, the viability of the present black-led government must be demonstrated before substantial equity investment will be made by international mining companies. There is severe political friction with RSA, and Zimbabwe remains dependent upon RSA rail and port facilities for shipping a major portion of its chromium exports.

In order for the United States to reduce its dependence upon the USSR and RSA for chromium ore, it should actively support and assist Zimbabwean economic development. Through bilateral agreements, assurances of Zimbabwean ferrochrome will lessen US vulnerability to chromium shortages. The long-term effects of a viable Zimbabwe economy should reduce Soviet influence in South Africa and serve to neutralize Soviet efforts to destabilize the region.

Manganese. Manganese, which is critical to the US defense industry, has been considered a "war material" since US foundries cast barrels for cannons and plates for iron-clad warships. To produce every ton of steel 12 to 16 pounds of manganese are required.

The United States imports about 2.4 million short-tons of managanese and ferromanganese ores annually from South Africa, Gabon, Brazil, Australia, and Mexico. The RSA is the major supplier of ferromanganese to the United States and the Free World industrial nations. The USSR and RSA have 80 percent of the world's manganese ores, reductions of Soviet exports have forced the other COMECON countries to import manganese from non-Communist suppliers.

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*Note that in March 1981, 36 member nations of the World Bank, with the UK and United States leading, pledged two billion dollars in aid over a three-year period for Zimbabwe development.[51]

US and North American resources are substantial but of low-grade ore quality. The developmental cost of these reserves prohibit their exploitation, given the present market conditions which are completely dependent upon RSA supplies of medium to high-grade ferromanganese ore. Since the COMECON members are net importers of manganese ore, they are competing in the Free World market for higher grade ores and thereby do not control the market.

While some critical minerals may be conserved, as we have experienced with recent oil shortages, the requirement for manganese ores in steel production does not offer any realistic possibilities for conservation efforts on a national or Free World basis. Similarly, there are no substitutes for manganese in the production of steel or in its other uses. Research for processing changes and alternative techniques in the use of manganese has not produced any results which would permit large scale conservation of manganese ores. The result is that the most practical and expeditious manner of insulating our defense industries from a disruption in the supply of manganese and ferromanganese ores is stockpiling a minimum three-year supply of those grades of ores that are critical to defense uses, according to FEMA objectives. Such stockpiling should permit the United States to continue defense production through a short-term conflict.

On a world-wide basis, it appears that there are unlimited reserves of manganese ore without considering the potential of seabed mining. Of the world's resources, the RSA claims some 50 percent; USSR has 35 percent; Australia and Oceania, 5 percent; North America, 3 percent; and South America, 2 percent. Present market conditions for manganese and ferromanganese ores indicate that there is a surplus of ores available, which should permit the maintenance of the US stockpile at a relatively economic price.

Given the necessity to stockpile manganese ores and the strong national defense posture adopted by the Reagan Administration, the US Government should maintain an active stockpile policy for manganese. No other practical alternative exists for guaranteeing critical supplies for defense production. The United States may subsidize the maintenance of manganese stockpiles or make direct purchases of the ores that are required. Other governmental actions may be seen in the subsidizing of the few ferromanganese conversion plants that still operate in the United States. The Reagan Administration will continue its objections to Law of the Sea (LOS) Treaty provisions which, if adopted by the United States, would force American deep sea mining firms to share technology and profits with with LOS signatories and subject US sovereign rights to directives of a multi-national LOS central governing authority. Additionally, Western industrialized countries and Japan should be encouraged to stockpile supplies of manganese under programs similar to that of FEMA.

Since southern Africa represents our largest supplier of manganese ores, the United States must maintain a flexible foreign policy toward reducing and stabilizing the conflicts that exist between black Africa and the RSA. US foreign policy must consider the need for continued supplies of critical minerals from the RSA, Zaire, Zimbabwe, and Gabon, and oil from Nigeria. Continued negotiations for the indepedence of Namibia within the framework of the "Contact States" proposals is an essential element of US foreign policy in southern Africa. We cannot permit the Soviet efforts to destabilize these negotiations through their exploitation of African nationalists.

On the domestic front, it is necessary to adopt a more critical review of the laws that adversely affect the economic condition of manganese ore producers, processors, and consumers. It is evident that environmental laws, Occupational Health and Safety Administration (OHSA) regulations, and tax and antitrust laws

have adverse effects upon the manganese industrial sector, which gives foreign processors economic advantages over US processors. Government agencies such as the EPA, Justice Department, State Department, Treasury Department, and the Defense Department should coordinate closely to avoid counterproductive policy actions that destroy American production capability, price our producers out of the market, and make us more dependent upon foreign producers and processors of manganese ore.

Bilateral treaties and agreements should be pursued with the smaller producers of manganese ore, such as Brazil, Gabon, Mexico, and Australia. Here economic aid and trade agreements can be coordinated with our need for continued supplies of manganese ores.

Through stockpiling of the necessary grades of manganese ores for a three-year supply, the United States should be able to sustain defense production during any short-term conflict. If supplies of manganese are not maintained, the effect on US defense industries will be devastating since no steel could be produced. This is the major reason why RSA and Gabonese supplies of manganese constitute a strategic vulnerability to the United States. We could obtain substantial supplies from Brazil, Mexico and Australia, although we would be lacking some quantities of high-grade ferromanganese.

As a contingency toward a conflict situation, the United States should maintain its industrial capacity to convert manganese ores to ferromanganese in the event foreign processors were not available. This may require government subsidies in order to modernize existing conversion plants. We could process stockpile ore into grades required for steel production, while these plants remain operable and then maintain stockpiles of the ferroalloy product. If the availability of manganese was restricted through some conflict, the rationing of stockpiled ferromanganese for military purposes may be imposed.

Platinum Group Metals. While vital to national defense industries, PGM's offer considerably more flexibility in end-use applications than chromium and manganese. Through electro-chemical processes, PGM's can be recovered and recycled which satisfies 7 percent of platinum requirements and 12 percent of palladium demand. The PGM-using industries have found some substitutes to the precious metals. Conservation is a more realistic contingency for PGM shortages, especially if production of automotive emission controls was suspended during periods of foreign supply disruptions. Additionally, supplies from Canada and UK might be increased if access to RSA exports were blocked.

The end-uses of PGM's are vital, underlying processes supporting US defense industries. Stockpiling offers the best short-term contingency for management of supply disruptions. The purchase of minerals for stockpiling is based on priorities established by the Annual Materials Plan, regardless of market conditions. However, current depressed mineral prices offer the United States excellent opportunities for purchasing supplies of platinum, palladium and iridium at considerably reduced costs, if funds were allocated with more flexibility. Additionally, research by the US Bureau of Mines on processing of domestic PGM ores and the recovery of PGM content from electronic scrap and electrochemical wastes should be fully funded and aggressively pursued. Development of domestic ores, recycling of PGM's from scrap and industrial processes, and substitution of other, less critical metals for PGM's in electronic and automotive uses offer real opportunities to conserve PGM's and substantially reduce US dependence on RSA and USSR supplies.

Movement of Supplies. The LOC's for the movement of required supplies of chromium, manganese and PGM's are well-established. The supporting transportation infrastructures of RSA, Zimbabwe, Mozambique and Gabon are relatively modern

systems, with sufficient cargo handling capacities to satisfy world demand for these ores. Occasional port congestion and labor unrest have not materially affected ore shipments. The potential for guerrilla actions against rail and port facilities in RSA and Mozambique is increasing and should be closely monitored by US authorities in order to avoid portracted disruptions of supplies. Prudent stockpile management and purchase from alternate sources should be pursued.

The SLOC's vary greatly in length and shipping cost, depending upon the ore exporting country and the location of the US port receiving the supplies. This exposure of established and relied-upon SLOC's to Soviet surveillance, influence and possible interdiction poses a strategic vulnerability US planners must consider. Supplies of these minerals are moved through sea lanes around southern Africa and through the South Atlantic, where there are no US Navy bases and relatively few ships or aircraft. It does not appear that the United States and/or its allies can match Soviet naval presence along vital sea lanes and choke points around Southern Africa without conducting regular calls at RSA ports.

Such bilateral arrangements with the RSA white supremist government may risk too heavy of a political price at the expense of US and West credibility with black African states. UK and US air and naval presence around Ascension and St. Helena Islands in the South Atlantic offers some means of monitoring Soviet activities in that area. Furthermore, Soviet diplomatic and economic actions designed to destabilize the competitive position of US-controlled shipping of bulk cargoes must be closely monitored and countered. If UNCTAD adopted a Soviet-inspired plan to boycott and otherwise ban the use of flags of convenience ships by Third World ore exporters, US shipping interests would be adversely affected.

Table 1: US NET IMPORT RELIANCE

Mineral	Imports for Consumption*		% of Apparent Consumption		Major Foreign Sources
	1981	5 Yr. Ave. [1977-81]	1981	5 Yr. Ave. [1977-81]	
Chromite	766.6	870	90	90.6	Republic of South Africa (RSA), 44%; Philippines, 16%; USSR, 15%; Finland, 9%; Other, 16%
Chromium Ferroalloys	272.2	238	90	90.6	RSA, 71%; Yugoslavia, 11%; Zimbabwe, 7%; Sweden, 4%; Other 7%
Manganese Ore	426.4	489.5	98	98	Gabon, 40%; Brazil, 19%; Australia, 15%; RSA, 14%; Other 12%
Ferromanganese	655	600.7	98	98	RSA, 39%; France, 25%; Other 36%
Platinum Group (1,000 Troy ounces)	2,025	2,328.4	84	88.6	RSA, 55%; USSR, 18%; UK, 11%; Other 16%

*Imports by 1,000 metric tons gross weight

Compiled by US Bureau of Mines, Mineral Commodity Summaries, 1982.

Table 2: MINERAL USES

Mineral	Using Industry	End Use	Military End Items
Chromium	Metallurgical (57%) Chemical (25%) Refractory (18%)	Construction (19%) Machinery Equipment (17%) Transportation (12%) Refractories (12%) All other (40%)	Aircraft engines, Missile parts, All weapons systems, ships and vehicles requiring steel structure, armor, barrels, etc.
Manganese	Metallurgical (95%) Chemical (5%)	Construction (23%) Transportation (20%) Machinery (16%) All other (41%)	All items requiring iron or steel, batteries
Platinum Group Metals	Automotive (30%) Electrical (26%) Chemical (14%) Dental (12%) Other (10%)	Catalytic Converters Communications Electronic Equipment Petroleum Refining Dental Devices Jewelry Glass Fibers	Electrical contacts, Sparkplugs, Fuse Wire, Emergency power units

Table 3: WORLD MINE PRODUCTION AND RESERVE BASE

Mineral	Source	Mine Production 1980	1981 (est.)	Reserve Base
Chromite	United States	--	--	--
	Finland	175	163	25,400
	Philippines	572	544	3,000
	South Africa, Republic of	3,415	3,100	2,268,000
	Turkey	400	372	5,000
	Zimbabwe	554	526	1,000,000
	Other Market Economy Countries*	1,038	935	13,000
	Central Economy Countries**	3,576	3,357	20,400
	World Total	9,730	8,997	3,334,800
Manganese	United States	--	--	--
	Australia	1,961	2,000	300,000
	Brazil	2,177	2,086	86,200
	Gabon	2,146	1,633	144,300
	India	1,646	1,633	45,400
	South Africa, Republic of	5,695	6,000	2,000,000
	Other Market Economy Countries	1,105	1,000	57,200
	USSR	10,250	10,340	2,177,300
	China, People's Republic of	1,588	1,542	45,400
	Other Central Economy Countries	128	90	22,700
	World Total	26,696	26,324	4,878,500
Platinum Group Metals	United States	3	6	16,000
	Canada	405	350	9,000
	South Africa, Republic of	3,100	3,100	970,000
	Other Market Economy Countries	72	74	NA
	USSR	3,250	3,250	200,000
	World Total	6,830	6,780	1,195,000

*Countries in which commodity prices are fixed by supply and demand dynamics of the market.

**Prices are fixed by central governing authority: Albania, Bulgaria, China (PRC), Cuba, Czechoslovakia, East Germany, Hungary, Kampuchea, North Korea, Laos, Mongolia, Poland, Romania, USSR and Vietnam.

NOTE: Chromite and manganese mine production and reserve base levels are in units of 1,000 metric tons; PGM's are in 1,000 troy ounce units.

Table 4: US STOCKPILE STATUS*

Material	Goal	Total Inventory	% of Goal
Chromite:			
Metallurgical-grade	2,903	1,775	61
Chemical-grade	612	220	36
Refractory-grade	771	355	46
Chromium ferroalloys	318	688	217
Chromium metal	18	3.6	20
Manganese:			
Battery: Natural Ore	56	168	300
Synthetic dioxide	23	2,7	12
Chemical ore	154	200	130
Metallurgical ore	2,450	2,185	89
Ferromanganese:			
High carbon	398	544	136
Medium carbon	--	26	--
Silicomanganese	--	21.7	--
Electrolytic metal	--	12.7	--
Platinum Group Metals:			
Platinum	1,310	453	35
Palladium	3,000	1,253	42
Iridium	98	17	17

*As of 11/30/81, but representative of current status in 1,000 metric tons units; PGM's are reported in 1,000 troy ounce units.

Table 5: LINES OF COMMUNICATION (LOC's)

Country & Commodity (Ann. Prod. 1,000 MT)	Movement to Port (LOC's)	Port Facilities	Movement to US Ports (SLOC's/ALOC)
Republic of South Africa:			
Chromium Ores (3,400)	High capacity rail & highways from BUSHVELD mining complex in TRANSVAAL area NW & NE of PRETORIA to port of DURBAN or by rail to port of MAPUTO, MZ.	DURBAN, RSA: Deepwater wharf for large ore carrier; special handling equipment @ 300 tons/hr.; many cranes; large open storage area.	Ore carriers of 20,000 to 50,000 DWT travel average of 7,600 n.mi. to US Gulf and Atlantic coast ports; BURNSIDE, LA; BALTIMORE, MD; & CHARLESTON, SC. 530,000 MT of ore landed.
		MAPUTO, MZ: Deepwater wharf for large ore carrier; ore loading facilities @ 2,000 tons/hr.; large open storage area.	
Ferromanganese (6,000)	High capacity rail & highways from ZEERUST-LICHTENBURG-KOSTER area west of PRETORIA, and HOTAZEL-SISHEN-POSTMASBURG area NW of KIMBERLEY to ports of DURBAN and PORT ELIZABETH.	DURBAN: (see above). PORT ELIZABETH; RSA: Deepwater wharf for large ore carrier; special handling equipment @ 1,300 tons/hr.; large open storage area.	SLOC same as above; vessels also land ore at inland ports via St. Lawrence Seaway and to PHILADELPHIA, close to steelmaking areas. 315,000 MT of ore landed.
Platinum Group Metals (PGM's) (3.1 million Troy ounces)	High capacity rail & highway from RUSTENBURG mining area W of PRETORIA to ports at DURBAN or PORT ELIZABETH: Concentrates and refined metal are shipped from nearby airports.	If seaborne, see above comments: PGM's shipped by air freight from PRETORIA-area airports.	If seaborne, see above comments; ALOC for PGM's from one or more modern airports outside PRETORIA to several major US airports in NE for delivery to 90-100 PGM processors/retailers in NE corridor. 1,28 million Troy ounces landed.

Table 5: LINES OF COMMUNICATION (LOC's)

(Continued)

Country & Commodity (Ann. Prod. 1,000 MT)	Movement to Port (LOC's)	Port Facilities	Movement to US Ports (SLOC's/ALOC)
Zimbabwe: Chromium ore (550)	High capacity rail & highway from mining areas along N-S axis of Great Dyke range W of SALISBURY, near GWELO and in BUHWA area to MAPUTO, MZ or DURBAN, RSA, for shipment.	MAPUTO, MZ: see above comments. DURBAN, RSA: see above comments.	SLOC same as for RSA chromium ores. See above comments. 20,000 MT shipped to US ports.
Gabon: Manganese ore (2.1 million MT)	Cable-railway system from MOANDA mining area, 48 mi. to MBINDA railhead in Congo(B); high capacity railroad 300 mi. to port at POINTE NOIRE; highway transportation not sustained; Note new rail line between MOANDA and port at OWENDO under construction.	POINTE NOIRE, CONGO (B): Deepwater wharf for large ore carrier; specialized ore handling facility @ 1,000 tons/hr.; large open storage area.	Bulk Cargo vessels average 6,350 mi. to Gulf Coast ports, BURNSIDE, LA; inland ports via St. Lawrence Seaway; and Atlantic ports of BALTIMORE, PHILADELPHIA & CHARLESTON, SC. 170,000 MT ore landed.

Data compiled from: Ports of The World - 1981; Shipping World, London; Jane's World Railways and Rapid Transit Systems, 1980-81; Development of a Standardized US Flag Dry-Bulk Carrier, US Maritime Administration, 1977.

Table 6: EFFECTIVE US CONTROL (EUSC) FLEET

June 30, 1981

	Total		Liberian		Panamanian	
	Number*	DWT	Number	DWT	Number	DWT
Total - All Ships	481	50,722,636	109	44,956,453	86	5,714,693
Dry Cargo	140	6,395,614	109	6,093,388	24	302,226
General Cargo	40	194,832	18	130,589	15	64,243
Bulk Cargo	100	6,200,782	91	5,962,799	9	237,983
Passengers	3	27,278	-	-	2	17,412
Tankers	320	44,071,453	260	38,676,398	60	5,395,055
Major Types	299	43,398,325	243	38,146,190	56	5,252,135
Others	21	673,128	17	530,208	4	142,920

*Included in this total are 7 Honduran reefer cargo vessels totalling 41,624 dwt.

Source: Effective US Control (EUSC) as of June 30, 1981
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50. Ibid., pp. 23-24.

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This paper examines the importance of three critical minerals: the platinum group, chromium and manganese. It outlines their uses, sources, transport and processing as they relate to US defense and industrial base.

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